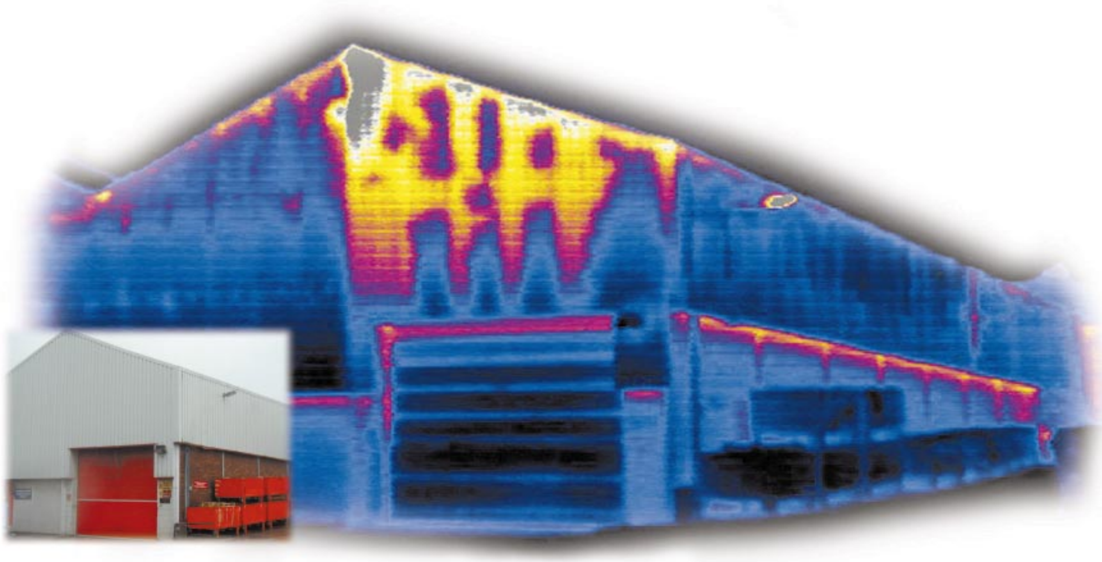
# Benchmarking tool for industrial buildings

## – heating and internal lighting

An easy-to-use software tool for benchmarking your building's energy use:

- sets site-specific benchmarks
- identifies scope for savings
- identifies and prioritises possible cost-effective energy-saving measures, based on input data





ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

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If you are already familiar with the benchmarking process, you may wish to use the FASTRACK ROUTE through this Guide. The route is indicated by the headings in the contents, and throughout the Guide by the symbol

This Guide is written for designers, client organisations, energy managers, building services engineers, and others with responsibility for monitoring and promoting energy management in industrial buildings. It may be of value to senior financial management, developers and landlords when considering energy audits and benchmarking of groups of industrial buildings across an estate.

The Guide explains the use and functionality of the ‘energy benchmarking tool’ and how to make best use of its findings. The software tool (on the accompanying CD) is designed to be used for buildings heated by fossil fuel ie gas, oil, or coal. Small amounts of electric heating can be incorporated, but as the use of electric heating increases the methodology becomes unreliable and so the tool should not be used where electric heating is greater than 20% of the fossil fuel heating.

The Guide has been developed under the Government’s Energy Efficiency Best Practice programme (EEBPp), the building-related aspects of which are managed by the BRE Sustainable Energy Centre.

Front cover shows thermographic images of a typical industrial building showing heat loss from the fabric.

# 1 INTRODUCTION

Good practice benchmarks are issued by the Government's Energy Efficiency Best Practice programme for most building types. The good practice benchmark can be achieved in well designed buildings using existing technologies and good energy management practices. The benchmarks set a standard for energy performance, which is usually better than the requirements of the Building Regulations in force when the building was built. However, as the Building Regulations are revised to take account of improved technologies, what was previously good practice becomes the 'norm'. The benchmarks then need to be revised to set 'good practice' at a new, lower consumption level. The benchmarks in this Energy Consumption Guide (ECON 81) replace those in the previous consumption guide for industrial buildings, ECON 18.

### DESIGN TARGETS FOR NEW BUILDINGS

The benchmarks in this Guide are based on surveys and analysis of the energy consumption in existing buildings. Improvements in technology will allow new buildings to achieve even lower energy consumptions. For example, the post-1995 heating benchmark uses a modest heating system seasonal efficiency of 70%, but decentralised, warm air and radiant heaters can deliver significantly higher seasonal efficiencies. A target for design purposes 10% below the post-1995 heating benchmark would not, therefore, be unreasonable.

For lighting, the benchmarks in circuit Watts per square metre are based on what is achievable with the lamps and luminaires described in this Guide, ie 2002 technology. To reach values better than these will require the greater use of modern technology, such as T5 fluorescent lamps which, as yet, are not widely used in existing industrial buildings.

For further information see GPG 303 – The designer's guide to energy-efficient buildings for industry.

## Heating benchmarks

The benchmarks for heating existing buildings are based on surveys of over 50 industrial buildings covering a range of ages, sizes and industrial processes. These surveys have shown that where older buildings are refurbished to a good standard, they can have an energy performance similar to that of more recent buildings (see figure A4.1). The new benchmarks in this Guide set standards against which the scope for further improvements to existing buildings can be assessed, taking account of improved technologies and the requirements of The Building Regulations 2000, Approved Document L2 (2002) which came into effect in April 2002.

These regulations set significantly higher levels of insulation and air tightness than the previous 1995 edition of the regulations, which in turn set higher standards than earlier regulations. Furthermore, the latest regulations require that material alterations to existing buildings meet the standards for new buildings. However, it may not be possible to justify the investment required to completely refurbish older buildings, in such a way that they are brought up to the energy performance standards now required for new buildings. To address this issue of what is economically viable, this Guide defines two benchmarks, one for buildings constructed since the Building Regulations 1991, part L1; 1995 edition came into effect and one for buildings constructed before these regulations came into force. The benchmarks are defined as:

***Post-1995 benchmark:*** the level that can be achieved by installing sufficient energy saving measures into a post-1995 building to improve its heating energy performance to the level that would be achieved in a building complying with the Building Regulations 2000, Approved Document L2 (2002).

***Pre-1995 benchmark:*** the level that can be achieved by installing sufficient energy saving measures into a pre-1995 building to improve its heating energy performance to the level achievable in a building complying with the Building Regulations 1991, Approved Document L1 (1995).

The benchmarks are defined in this way to set a scale against which the performance of existing buildings can be assessed. This does not preclude refurbishing pre-1995 buildings to the post 1995-benchmark level.

Smaller buildings are generally more difficult to heat than larger ones. This Guide therefore provides benchmarks for buildings with areas of up to 5,000 m$^2$ and over 5,000 m$^2$.

## 2 ABOUT THE TOOL

**Energy-intense processes**

The impact of process energy is often overlooked when assessing the heating requirements in a factory. Where energy-intensive processes release more heat into the space than that required to heat the building, it may not be possible to reliably identify the energy used by the building's heating system, unless it is separately sub-metered. Where not sub-metered, benchmarking of the building may not be possible.

The tool checks the input data to ensure that the assumptions behind the methodology remain valid.

There is always pressure on businesses to increase profitability. One way of increasing profits is to reduce operating costs, of which energy cost is one.

It is estimated that up to 50% of energy savings in industrial buildings can be achieved through addressing one or more of the following factors:

- poorly insulated buildings
- uncontrolled ingress of cold external air
- inadequate heating systems and controls
- no clear maintenance regime
- heat distribution losses
- wrongly set thermostats
- inefficient lighting installations and controls.

This Energy Consumption Guide describes an 'energy benchmarking tool' that has been developed specifically for industrial buildings where fossil fuels (gas, coal and oil) are used as the heating fuel.

This software tool can be found on the accompanying CD (see pocket on the inside back cover of this Guide), which will run on most PCs operating under Windows 95 and above, and running the Excel spreadsheet program.

The benchmarking tool offers a rapid way of assessing the energy efficiency of heating and lighting for a particular industrial building or group of buildings. It also identifies the potential for energy savings (typically 20% to 50%).

This Guide incorporates case studies to illustrate how the benchmarking tool manipulates energy consumption data to arrive at site-specific benchmarks. The case studies, inserted in the back pocket of the Guide, also show how the various organisations can benefit from implementing some of the prioritised measured shown on the summary reports.

Benchmarking is essentially a three-stage process:

- calculate the building's performance indicator (PI) – see Section 3
- calculate the site specific benchmark – see Section 3
- compare the PI with the site-specific benchmark; this will reveal the potential for saving.

The energy benchmarking tool calculates the performance of your building(s) and a site-specific benchmark, based on the data you enter. It then compares performance with the benchmark and produces a summary report. The report indicates those measures, specific to the benchmarked building(s), which are most likely to improve energy performance.

As with any computer-based calculations, it is important to remember that the quality of the calculations and, in particular, the summary report, is only as good as the information provided. (Remember the adage 'Garbage In Garbage Out'?) Therefore, in order to make the best use of the tool, you should first read this Guide. It will help you to review and assess the activities within the particular industrial building or group of buildings before you proceed with the benchmarking process.

### Benefits of using the tool

The tool automatically:

- compares the building's energy performance with site-specific benchmark
- identifies the buildings-related element of the site's total energy consumption
- identifies and prioritises possible cost-effective energy-saving measures, based on input data.

One unique aspect of the benchmarking tool is that it takes account of process energy. The tool undertakes separate calculations for where process energy has a minimal or a significant impact on a building's heating energy performance.

# 3 PERFORMANCE INDICATORS AND BENCHMARKS

## PERFORMANCE INDICATORS

This Guide uses the term 'performance indicators' (PIs) to describe energy performance. PIs can be measured in terms of:

- energy consumption
- energy costs
- carbon emissions.

This Guide uses PIs based on energy use:

- heating – kWh/m$^2$
- lighting – circuit W/m$^2$.

Conversion factors for different fuels and units are shown in Appendix 5.

The heating and lighting benchmarks are the PIs achievable through using good practice.

## HEATING BENCHMARKS

The heating benchmarks are based on a standard set of conditions representative of the circumstances and working practices at typical industrial sites:

- all areas heated to 19°C during occupied periods
- decentralised, responsive heating system
- normal site exposure
- 5-day, single 8-hour shift
- 2051 degree days for 15.5°C base temperature over the heating season (September to May inclusive)
- optimum pre-heat periods and set back temperatures during unoccupied periods
- air change rate of 0.8 air changes per hour (ach) for small buildings and 0.5 ach for large buildings.

### Site-specific heating benchmarks

The heating of industrial buildings depends on a large number of interrelated factors. One of the most important is the internal temperature, which should be appropriate for the activities being performed. For people doing physically demanding work an internal temperature of 13°C may be adequate, while for those undertaking sedentary work, temperatures of around 19°C are appropriate, although many people prefer temperatures one or two degrees higher. Intermittently occupied areas such as stores/warehouses may only need to be heated to frost or condensation protection temperatures.

Other factors that affect the energy consumption are:

- the length of the working week
- the age and condition of the building fabric, especially its airtightness
- the exposure of the site and the degree days for the factory locality.

The type of construction – lightweight or medium-weight – influences the benchmarks through its effect on pre-heat times. The vast majority of industrial buildings are lightweight, including those surveyed for this Guide.

Some older industrial sites, particularly those based in old mill premises, may have medium-weight buildings, ie single-storey buildings of masonry or concrete with solid partitions. Medium-weight buildings require longer pre-heat periods, which will increase the energy consumption. (Approximated 'good practice' benchmarks for heating in medium-weight buildings are given in Appendix 2, Table A2.3.)

The floor area and height of buildings also affect the benchmarks, mainly through their influence on ventilation rates. Ventilation rates are measured in air changes per hour (ach), and are generally lower in large volume buildings than small volume buildings.

You need to take account of all these interrelated factors if comparisons between your building's performance and the benchmarks are to be meaningful. For example, Figure 1 (overleaf) shows how the benchmark would be affected (in percentage terms, on the vertical axis) if the key factors of air change rate (acr), internal height and internal temperature are varied (along the horizontal axis).

| Factory area heated by fossil fuel (m$^2$) | Benchmark consumption (kWh/m$^2$ per year) | |
|---|---|---|
| | Post-1995 | Pre-1995 |
| | Lightweight | Lightweight |
| Up to 5,000 | 96 | 107 |
| Over 5,000 | 92 | 103 |

*Table 1 'Good practice' benchmarks for heating in lightweight industrial buildings*

# PERFORMANCE INDICATORS AND BENCHMARKS

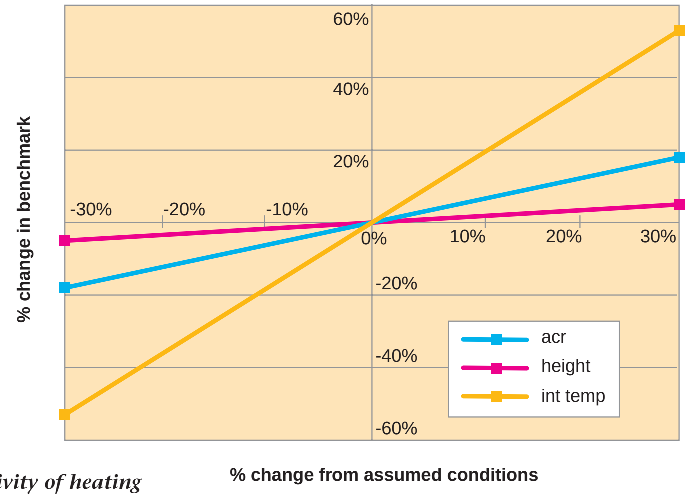



*Figure 1 Sensitivity of heating benchmarks to key variables*

The graph shows that the benchmark is most sensitive to changes in internal temperature, with only a 10% change in temperature altering the benchmark by 20%. In other words, a factory running at 18°C would have a site-specific benchmark 20% lower than the same factory running at 20°C (assuming all other factors remained unchanged).

The next most sensitive parameter is the air change rate. A change of approximately 30% will result in the site-specific benchmark differing by nearly 20%.

At a constant ventilation rate (in volume terms), the building's height has little affect on the 'good practice' benchmark, reflecting the fact that the heat losses through the walls are a relatively small part of the total heat loss.

### LIGHTING BENCHMARKS

Surveys of installed lighting systems have shown that, in most instances, general lighting levels are, at best, approximately known, and vary from under-lit to over-lit. The general 'good practice' lighting benchmarks in this Guide are, therefore, calculated installed loads given in circuit Watts per square metre (W/m$^2$) for specified light levels. The 'good practice' benchmarks are achievable using efficient (high-efficacy) lamps in luminaires having a high light output ratio.

Table 2 (below) provides 'good practice' benchmarks for general lighting in large open spaces for which room indices are greater than 3 (where room index = (L x W)/(H x (L+W)) where L is the length of the room, W is the width and H is the height of the luminaires above the working plane; and 'open' implies no significant obstructions above the working plane.

The level of lighting required in such areas depends on the discrimination of detail needed:

- Where no discrimination of detail is needed a lighting level of 300 lux is usually sufficient.
- For medium discrimination of detail, 500 lux is usually required.
- Where fine discrimination of detail requires lighting levels greater than 500 lux, dedicated task lighting should be used.

With few exceptions, it is not good practice to light a whole area to match the level required by tasks which need high illumination levels (greater than 500 lux).

| General factory lighting | Benchmark consumption (W/m$^2$) | |
|---|---|---|
| | 300 Lux | 500 Lux |
| General lighting for 'open' areas | 5 – 6 | 8 – 10 |

***Table 2 'Good practice' benchmarks for lighting in industrial buildings – for mounting heights up to 9.5 metres and maintenence factor of 0.8***

***Notes:***

(1) For metal halide lamps, the Society of Light and Lighting's 'Code for lighting 2002' recommends slightly higher targets for the average installed loads of 7 W/m$^2$ at 300 lux and 12 W/m$^2$ at 500 lux.

(2) The lighting benchmarks and PIs can be converted to kWh/m$^2$ per year by multiplying by the hours of operation and a management factor to allow for the extent to which the lights are dimmed or turned off in response to available daylight.

## PERFORMANCE INDICATORS AND BENCHMARKS

### Choice of lamps

A key factor influencing the choice of lamps and luminaires is the mounting height above the working plane. Lamp ratings (wattages) and spacing must be appropriate for the mounting height, to obtain uniform lighting and avoid glare. The choice is predominantly between fluorescent and high-pressure sodium lamps.

Some factories have metal halide lamps installed when good colour rendering is required (Ra>60). The target installed loads are slightly higher than those achievable using fluorescent or high pressure sodium lamps (see footnote to Table 2). Provided that high-efficacy lamps are used with luminaires having high light output ratios, it is found that the installed load for a given lux level does not vary significantly with mounting height, and there is little to choose between fluorescent lamps and high-pressure sodium lamps.

This means that good colour rendering can be achieved using fluorescent lamps for the same installed load as for high-pressure sodium.

Where good colour rendering is not required, practical considerations, such as the number of lamps and installation costs, favour high-pressure sodium for mounting heights greater than about 4.5 metres.

Guidance on lighting other spaces in the factory with room indices of around 2.5 (eg integral offices) can be found in 'Code for Lighting 2002' published by the Society of Light and Lighting[1].

### Lighting of racked storage areas

This depends on the aisle widths and the mounting height of the luminaires. Where no discrimination of detail is needed an average lighting level of 150 lux (measured on a horizontal plane) is usually sufficient. For medium discrimination of detail 300 lux is required. The 'good practice' benchmarks in Table 3 are based on the lit area of the aisle.

Appendix 2 gives information on selecting lighting levels and corresponding benchmarks for use in the benchmarking calculator calculations.

| Aisle width (m) | Mounting height (m) | Benchmark (W/m$^2$) | |
|---|---|---|---|
| | | 150 Lux | 300 Lux |
| 1.2 | 4.5 | 8 | 14 |
| 2.4 | 6.5 | 8 | 16 |
| 3.0 | 8.0 | 9 | 17 |

*Table 3. 'Good practice' benchmarks for installed power density in racked storage areas*

# 4 THE BENCHMARKING PROCESS

**Important note**
The tool requires temperatures to be entered for each activity area, but these temperatures should be the 'good practice' value appropriate to the activity.

## UNDERSTANDING YOUR FACTORY

Before embarking on the benchmarking process, you must consider the way in which the factory functions.

Office, production, warehouse and store activities impact differently on the required temperature and lighting levels. Therefore, before using the tool, you will need to have certain information ready at hand, including the areas for activities undertaken within each of the metered areas.

The information required is shown on the four blank data collection forms inserted at the back of this Guide; one each for:

- negligible process impact
- significant process impact (no metered process fossil fuel consumption)
- significant process impact (metered process fossil fuel consumption)
- lighting.

'Significant process impact' is where the process provides warming of the building's internal environment, or where the process requires ventilation.

You may find it more convenient to print out the appropriate sheet from the accompanying CD and complete it prior to using the tool.

The benchmarking process can be applied to a single metered area or a group of metered areas. If the objective is to identify where energy savings could be made, the process should be applied to each metered area individually. If the objective is to obtain an overview of the site's performance, it may be more appropriate to group metered areas together. In either case, you need to estimate the percentage of the total area occupied by each activity, such as, offices, production or warehousing. The activity areas should always add up to 100% of the area being benchmarked. For example, offices may occupy 20%, production 50% and warehouses/stores 30%, some of which may be racked (see Figure 2).

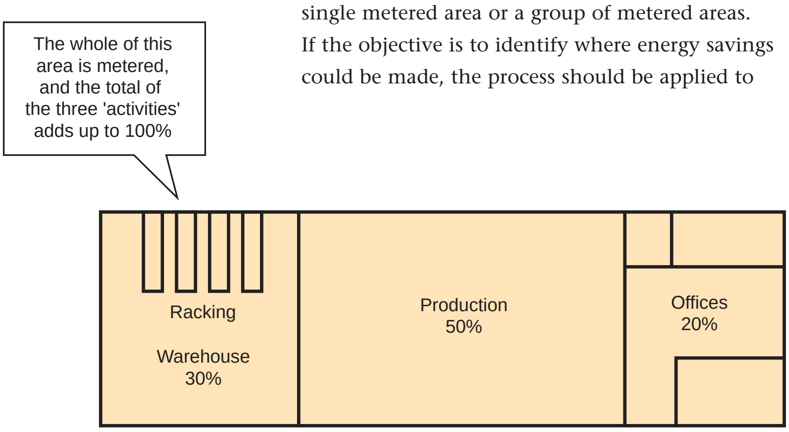



*Figure 2 Estimate of the total area occupied by activities*

Managerial and administration functions are carried out in office spaces that are often an integral part of the industrial building (ie they are not sub-metered). There will also be various ancillary areas for toilets, locker rooms, canteens, restrooms, and so on, which are best grouped with the office activity. Stores and warehouses may be heated or unheated.

For optimum efficiency, temperatures should be maintained at levels appropriate to the activity taking place and at levels that ensures comfortable working conditions. For people doing physically demanding work an internal temperature of 13°C may be adequate, while those undertaking sedentary work will require temperatures of around 19°C.

The hours of occupancy will often be different for offices and production areas. Intermittently occupied areas such as stores/warehouses may need to be heated to frost or condensation protection temperatures.

The methodology used by the tool requires you to supply data for each distinguishable activity area in the building, or area being benchmarked (see Section 5 and Appendix 2). The tool then calculates a weighted average benchmark for all the different areas in the building or complex, which can be compared with the PI.

The more accurate the assessment of the building at this stage, the more accurate the benchmarking calculations.

## THE BENCHMARKING PROCESS

The benchmarking process itself is relatively straightforward. The tool undertakes some simple calculations, based on data you supply, to produce a summary report.

There are three main benchmarking steps.

1. Calculate the PI for the building(s).
2. Calculate the site-specific benchmark by adjusting the 'good practice' benchmark to account for the circumstances at the factory.
3. Compare the PI with the site-specific benchmark to identify potential energy savings.

Having completed the calculations, the tool generates a report that identifies and prioritises possible cost-effective energy-saving measures for you to consider, based on input data.

### BENCHMARKING HEATING

#### 1. Calculating the heating PI

The heating PI (in kWh/$m^2$ per year) is the annual energy input into the building from all sources divided by the heated floor area, assuming that the building is heated by fossil fuel (gas, oil or coal).

- If the process has no impact on heating, you will only need data on annual fossil fuel consumption and heated floor area.
- If the process has a significant impact on the building environment, the benchmarking tool's built-in routines will take the weather-related part of the fossil fuel consumption, add the useful contribution from the process and subtract the extra heat load due to process-related ventilation and any heat rejected from the process. The calculated PIs are then for heating the building in the absence of the process, ie 'process neutral'. Values for process-related ventilation and heat rejected from the process need to be entered in the appropriate box on the data input screen for 'significant process impact'.
- If energy-intensive processes release more heat into the space than that required to heat the building, the thermal performance of the building is usually of little consequence and it is more important to concentrate on the energy efficiency of the process. Under these circumstances it may not be possible to identify the energy used by the building's heating system unless it is sub-metered. The tool tests the input data to check that the methodology remains valid (see Appendix 2).

#### Allowing for electric heating

Electric heating of industrial spaces is not good practice because of the high running costs and high carbon emissions at the power station per unit of delivered energy. Nevertheless, it is often found that small areas of a factory are heated by electricity, or that portable electric heaters are used to supplement the heating by fossil fuel. The energy consumed by such electric heaters is not usually monitored and the electricity meters record consumption by all end uses such as lighting, motors, IT equipment and possibly also the process. Provided that the electric heating is a small part of the total, ie not more than 20% of the fossil fuel input, it is possible to proceed with the benchmarking process. Note: Electric heating should not be compared with a fossil fuel benchmark, but provided the electric component is ≤ 20% the error is acceptable.

To estimate electric heating, press button within tool to open 'Electrical Heating' calculation sheet.

- For small electric heaters, estimate the electric heating by multiplying the rated power by the annual hours of operation.
- For night storage heaters, assume some proportion of the storage capacity in kWh is consumed for each day that the heaters are in use.

The estimated kWh of electric heating will not be very accurate, and where there is significant use of electric heating, ie more than 20% of the fossil fuel input, the calculated PIs become unreliable, and comparison with the fossil fuel benchmark is increasingly invalid.

#### Electrically heated warehouses

A special case has been set up in the Negligible Process Impact version of the tool for electrically heated warehouses where lighting and heating account for virtually all the metered electricity consumption. Firstly use the tool to calculate the lighting load. Multiply this by the hours of operation to obtain the kWh per year for lighting. Subtract this from the metered consumption to provide an estimate of the kWh per year for heating. Enter this estimate in the box for sub-metered electric heating consumption and then enter zero in the box within the tool for 'Annual fossil fuel' – this is important as it sets up the special case and provides further guidance.

To compare the electric heating (which is 100% efficient at the point of use) with the fossil fuel benchmark (based on a seasonal efficiency of 70%), the actual consumption must be divide by 0.7 and entered into the box provided for this special case.

# THE BENCHMARKING PROCESS

### 2. Calculate the site-specific benchmarks

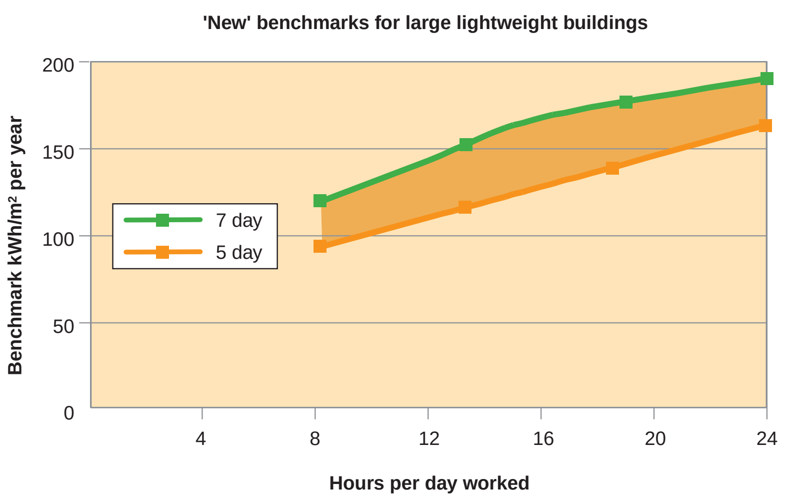
The 'good practice' heating benchmarks, which are for a standard set of conditions, need to be adjusted for the actual circumstances in the building(s) (see Appendix 2). This involves multiplying the 'good practice' heating benchmarks by factors to allow for differences in:

- good practice value for internal temperatures
- hours of occupancy
- exposure of the building
- degree days at the site
- centralised or decentralised heating system.

These factors are either calculated by the benchmarking tool using the input data, or selected from drop-down menus (see Section 5 and Appendix 2).

The adjustment factors for internal temperature and hours of occupancy will generally be different for each activity area. Figure 3 illustrates how the benchmarks vary with hours of occupancy.

*Figure 3 Variation of site-specific benchmark with hours of occupancy*




### 3. Comparing the PI with the site-specific benchmark

This gives an indication of the potential energy savings.

This simple benchmarking procedure is not an exact science and, as a result, differences of ±15% between the site-specific benchmark and the actual performance indicator are of no real significance. The purpose of the benchmarking is to identify those poorly-performing buildings, many of which are consuming two to three times, or even more, energy than the 'good practice' benchmark value.

The entries made on the data input sheets are used to generate a report for your site, that sets out the possible cost-effective energy saving measures that can be made. Further details of these measures are given in 'Focus – the manager's guide to reducing energy bills'[2].

## BENCHMARKING LIGHTING

For lighting, the installed load is calculated from the number of lamps installed in a given area and their circuit wattages (see Table 4).

General lighting levels are determined by the perception of detail that is needed. Selecting either the 'no detailed work' or 'medium detailed work' in the benchmarking tool automatically adjusts the benchmark to the appropriate lighting level and compares the installed load with the adjusted benchmarks.

Table 4 gives ratings for commonly used lighting in industrial situations. Note that the rating (wattage) of the lamp is not necessarily the same as the total circuit wattage of the fitting.

| Fluorescent (Note: EB = Electronic ballast, HO = High output) | | | | | |
|---|---|---|---|---|---|
| Description | Total circuit wattage | Description | Total circuit wattage | Description | Total circuit wattage |
| 2400 mm, Ø38 mm, 125 W tube | 137 | 1500 mm, Ø38 mm, 65 W tube | 78 | 1150 mm, Ø16 mm, 28 W tube, EB | 32 |
| 2400 mm, Ø38 mm, 100 W tube | 112 | 1500 mm, Ø26 mm, 58 W tube | 71 | 850 mm, Ø16 mm, 21 W tube, EB | 24 |
| 2400 mm, Ø38 mm, 100 W tube, twin | 229 | 1500 mm, Ø26 mm, 58 W tube, twin, EB | 108 | 550 mm, Ø16 mm, 14 W tube, EB | 17 |
| 1800 mm, Ø38 mm, 75 W tube | 91 | 1200 mm, Ø38 mm, 40 W tube | 51 | 1450 mm, Ø16 mm, 49 W tube, EB, HO | 54 |
| 1800 mm, Ø26 mm, 70 W tube | 80 | 1200 mm, Ø26 mm, 36 W tube | 47 | 1150 mm, Ø16 mm, 54 W tube, EB, HO | 59 |
| 1800 mm, Ø26 mm, 70 W tube, twin | 162 | 1200 mm, Ø26 mm, 36 W tube, twin, EB | 74 | 850 mm, Ø16 mm, 39 W tube, EB, HO | 44 |
| 1800 mm, Ø26 mm, 70 W tube, twin, EB | 132 | 1450 mm, Ø16 mm, 35 W tube, EB | 39 | 550 mm, Ø16 mm, 24 W tube, EB, HO | 28 |

| High pressure mercury (MBF) | | High pressure sodium (SON) | | Low pressure sodium (SOX) | | Metal halide (MBI) | |
|---|---|---|---|---|---|---|---|
| Lamp rating (Watts) | Total circuit wattage | Lamp rating (Watts) | Total circuit wattage | Lamp rating (Watts) | Total circuit wattage | Lamp rating (Watts) | Total circuit wattage |
| 50 | 62 | 50 | 62 | 18 | 26 | 125 | 172 |
| 80 | 94 | 70 | 86 | 35 | 52 | 250 | 288 |
| 125 | 142 | 100 | 114 | 55 | 68 | 400 | 410 |
| 250 | 275 | 150 | 172 | 90 | 105 | 1000 | 1080 |
| 400 | 430 | 250 | 280 | 135 | 175 | | |
| 700 | 720 | 400 | 432 | | | | |
| 1000 | 1040 | 1000 | 1090 | | | | |

*Table 4 Circuit wattages for commonly used lamp types*

# 5 USING THE TOOL

This Section guides you through the process of completing the various fields of the energy benchmarking tool.

Before starting to input data it will be useful to check that you have all the information required, because the tool will operate only when all entries have been made. (Refer to the blank data collection forms inserted at the back of this Guide.)

In particular, you will need to know at the start whether or not the impact of process energy is 'negligible' or 'significant', because this will dictate the data you need to collect to complete the benchmarking exercise.

If the impact of process energy is significant, you will also be asked to choose one of the following:

- when the process consumption is *roughly constant* each month use 'no metered process fossil fuel consumption'
- when the process consumption *varies* month to month use 'metered process fossil fuel consumption'.

## USING THE TOOL TO INVESTIGATE ENERGY-SAVING MEASURES

It is possible to use the tool to investigate energy saving measures – 'what if' scenarios. For example, entering a lower temperature for an activity area and going to the results screen will show how much the 'good practice' site-specific benchmark has been reduced. If your heating system is well controlled (see degree day plot), this reduction in the benchmark is indicative of the savings you can achieve.

For lighting, substituting details of more efficient lamps on the input screen for lamp types and numbers in place of your existing lamps will show you by how much the installed load in watts/$m^2$ can be reduced.

The tool is simple to use. Just enter the data into **ALL** the boxes on the various data input forms and make selections (where appropriate) from the drop-down menus. Each box has a ***HELP*** ? button which, when selected, opens up a window explaining what information is required.

Note that benchmarking lighting is a separate process from benchmarking heating, and should be applied to each lit area. These areas may not, of course, correspond to the heated areas.

## GETTING STARTED

When you first load the CD it should automatically open up a dialogue box, from which you are given the option of accessing the tool or viewing the pdfs of the case studies or the data collection sheets. Figure 4 (opposite) illustrates the stages that must then be completed.

Remember that the ***HELP*** ? button provides additional information as you go through the process of entering data on the various input forms.

Once all the data have been entered into the tool, it automatically carries out the benchmarking process and generates a report that identifies and prioritises possible cost-effective energy-saving measures, based on input data.

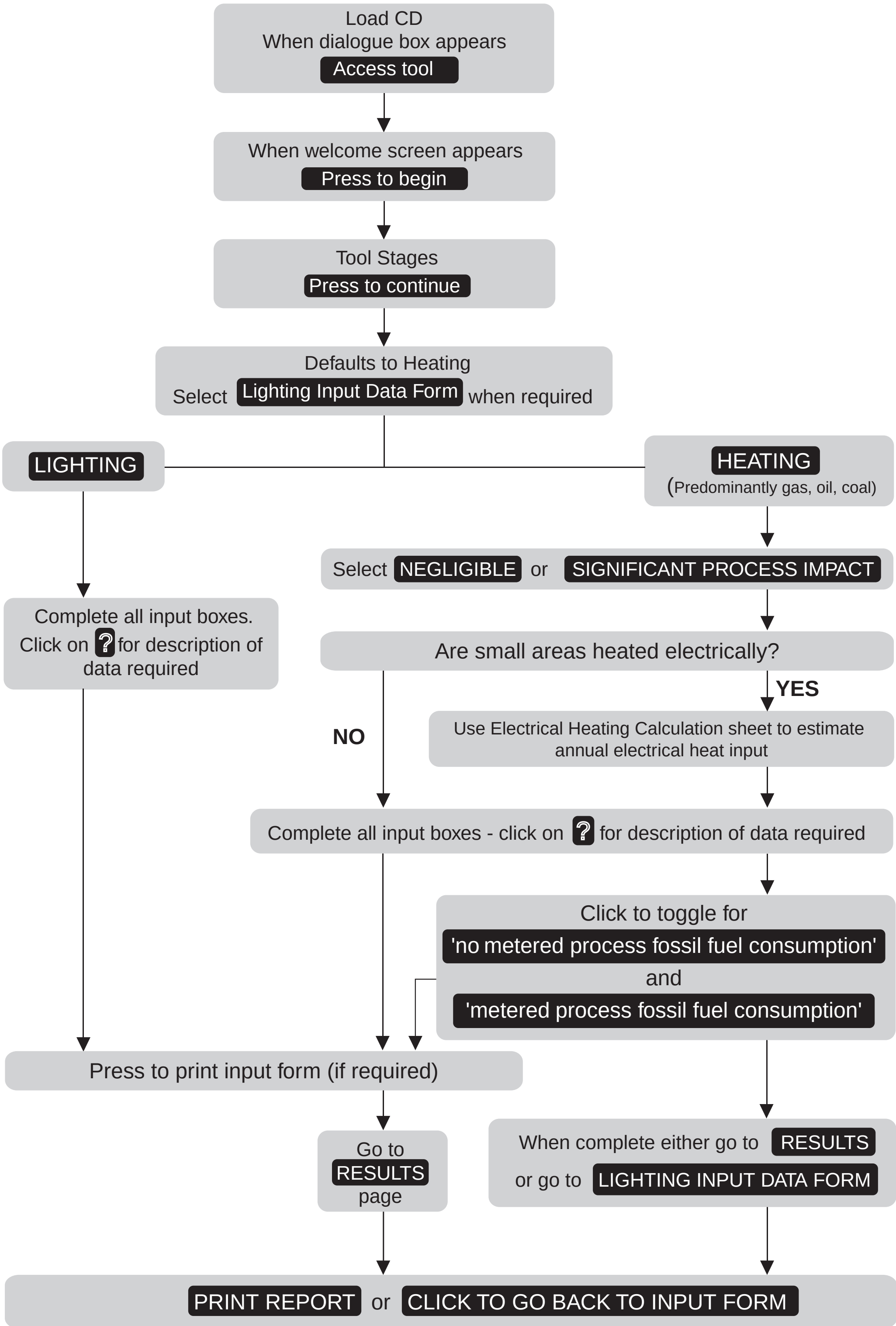
Check that you have input ALL the data requested and that the detail is correct, to avoid calculation failure.

You may wish to print out the completed data input screens as a record of your entries.

## USING THE TOOL

*Figure 4 Flow-chart illustrating the various stages of the benchmarking calculations*

Check all required data are available by using the appropriate data collection forms in the back of the Guide (or print out the appropriate forms from the CD)



# 6 RESULTS AND PRIORITISED ACTIONS

### ACTIONS TO REDUCE ENERGY COSTS

The benchmarking tool generates short reports for heating and lighting, prioritising possible energy-saving measures, based on the data you have supplied. An example of a heating report from one of the case studies is given in Figure 5.

### HEATING REPORT

Performance Indicator
Benchmark
Potential Savings
Correlation

| Building Details | | Performance indicator/benchmark | |
|---|---|---|---|
| Peterson Spring UK Ltd | Hewell Road | Heating PI kWh/m$^2$ per year | 264 |
| Mavis Yates | Redditch | Heating benchmark kWh/m$^2$ per year | 152 |
| | Worcestershire | Variance from BM (%) | 73.44 |
| 6/2/2002 | B97 5EH | Is data correlation within threshold | Yes |

*The percentage of your heating provided electrically is 0.76%. This is below the threshold (20%).*

**Recommendations based on the deviation from benchmark. (These relate to poor management control and infiltration of air through leaky fabric).**

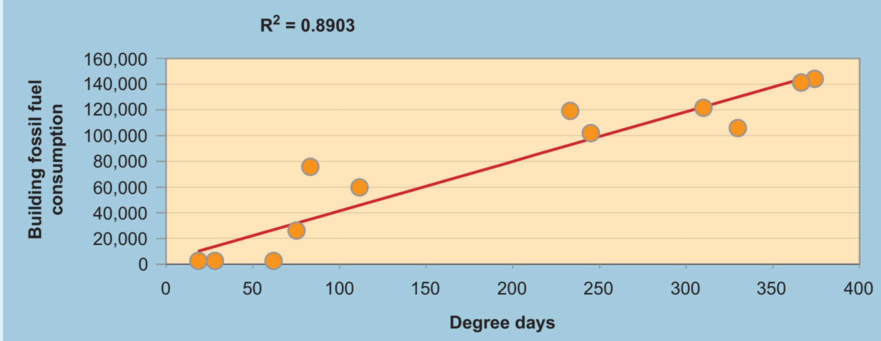
Summary

**Your heating PI is over 50% higher than the benchmark. This poor performance suggests that there is considerable scope for further savings. It is almost certain that the space temperatures are too high for the activities being undertaken and that the building is very draughty resulting in high heat losses.**

Measures to improve energy performance of the building

**Have you looked at ways of reducing draughts coming from loading areas?**
**eg roller shutter doors, strip curtains, etc**
Are all windows fitted with double or secondary glazing?
Have you considered insulating flat arid pitched roofs during re-roofing work?
Do your ventilation systems incorporate air recirculation or heat recovery?
Does your heating system incorporate an optimum start controller?
Do heaters automatically switch off when doors in loading bays, garages and work-shops are opened?
Are heated areas effectively separated from unheated areas?
Are windows, roof lights and doors draught-proofed?
Is your heating distribution pipework appropriately insulated?
Are staff encouraged to reduce their heating when they are too hot instead of opening windows and doors?

Data related to correlation coefficient




**Fossil Fuel Consumption by Degree Days**

**Recommendations made based on the degree day plot. (These relate to control issues).**

Measures to improve energy performance of the heating system

The small amount of scatter on your degree day plot suggests that the control of your heating system is relatively good.
Do you use weather compensated controls for radiator systems?
If you have radiant heaters are they controlled by black bulb thermostats?
Have you considered fitting thermostatic radiator valves (TRVs) to radiators in office areas?
Do you regularly check that heating and ventilation control valves and dampers are operating correctly?
Are radiators and other heating surfaces always unobstructed?
Are the settings of frost and night set back thermostats regularly checked?
Are your thermostats and temperature sensors located in the right place?
Are your thermostats and thermostatic radiator valves set to the correct temperature and then left alone?

*Figure 5 Sample heating report*

## RESULTS AND PRIORITISED ACTIONS

The results from one of the case studies (see inserts in the back pocket of this Guide) are reproduced opposite to illustrate the kind of information that can be obtained from the benchmarking process.

### Potential energy savings – heating

The benchmarking tool compares the PI with the site-specific benchmark and uses the difference to calculate the potential energy savings (see Table 5).

### Distribution of the heating load

A pie chart, such as Figure 6, can illustrate what the distribution of the heating load should be, based on the site-specific benchmark consumption for each activity area in the area being benchmarked. This will help you to direct attention in the first instance to the activity areas that account for most of the heating load.

The actual consumption in a particular area may be very much higher. Temporary sub-metering may be required to confirm the potential savings in a particular activity area in order to justify investing in energy saving measures.

### Degree day plot

The degree day plot (see report Figure 5) is used to verify that the underlying assumptions behind the benchmarking process are fulfiled. The correlation factor $R^2$ printed on the graph (Figure 5) is a measure of how closely the heat input to the building correlates with the number of degree days (see Appendix 3). A low correlation factor – less than 0.5 – would indicate that other influences, such as the process, are contributing to the variation in the monthly energy consumption. Under these circumstances the benchmarking tool will issue a warning and refer you to Appendix 3 for possible alternatives.

### POTENTIAL ENERGY SAVINGS – LIGHTING

The installed load (in circuit watts/m$^2$) is compared with the site-specific benchmark (for example, see Table 6). The difference is the potential for energy savings through improvements to the lighting system. Further savings may be possible through reducing the hours of operation of the lights.

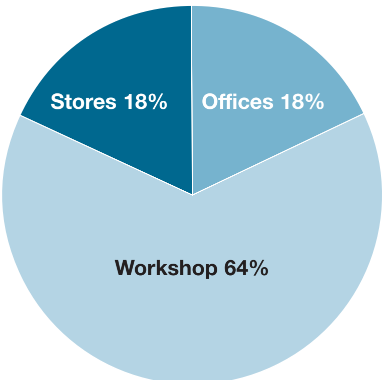



*Figure 6 Distribution of the heating load (To view pie chart click on the 'see pie chart' button in the 'activity area' screen of the tool)*

| PI (kWh/m$^2$ per year) | Site-specific benchmark (kWh/m$^2$ per year) | Potential savings (%) |
|---|---|---|
| 150 | 103 | 46 |

*Table 5 Example of heating PI compared to site-specific benchmark*

| PI (circuit watts/m$^2$) | Site-specific benchmark (circuit watts/m$^2$) (median value) | Potential savings (%) (based on median benchmark) |
|---|---|---|
| 7.5 | 5.5 | 36 |

*Table 6 Example of lighting PI compared to site-specific lighting benchmark*

# 7 COMMON SAVING OPPORTUNITIES

This Section provides general guidance on energy-saving measures. It should be read in conjunction with the prioritised list of energy-saving measures identified by the benchmarking tool.

## HEATING

### Temperature control

As discussed in Section 3, the most effective way of reducing the heating energy consumption of a building is to reduce the internal space temperature. Many industrial buildings, particularly storage and warehouse areas, are heated to temperatures higher than necessary, resulting in the site PI being well in excess of the site-specific benchmark.

Ideally, all buildings should be divided into zones for heating. Each zone should have local controls set to maintain temperatures appropriate to the activities taking place in each zone. The building may have areas where heat gains or losses are markedly different. If this is the case, a sophisticated temperature control strategy may be necessary.

### Time control

Good time control is fundamentally important to ensure that heating plant (and lighting) is switched off when not needed.

Simple time control will switch the heating system on at a pre-determined time. The heating plant will then run until the timer switches off the plant.

It will be necessary to have separate time controls for a factory where both warm air and radiant heating are utilised. The pre-heat time needed to ensure that the building is up to temperature by the start of occupancy will be different for each heating type.

A more sophisticated approach is to use an optimiser for time control. This uses the difference between the internal and external temperature to adjust the start (and sometimes stop) times so that the heating system pre-heats only for as long as necessary. These can usually also be used to provide frost protection, if the temperature in the building drops below a given fixed point.

### Measures to reduce air change rate

High air change rates in industrial buildings are frequently a cause of the fuel consumption being substantially higher than benchmarks. Even if there is no requirement to ventilate the process, air change rates can vary from 0.3 to over 3.5 ach due to leaky building fabric or large access doors being left open. Generally, air change rates are far in excess of that required to meet the needs of the occupants.

If air change rates are high, it will always be cost-effective to remedy any leaks in the fabric. Where it is necessary to have a large access door open, improving the air tightness of the fabric will reduce the flow of air through the building. Where the wind creates a pressure differential across the building, the through-flow when a door is open is roughly proportional to the leakage area in the fabric.

Once the fabric has been rendered airtight, the next most cost-effective measure will be to ensure that access doors remain open only for as long as necessary. Personnel can be trained to do this, but automatic controls with suitable safety interlocks are an option. For certain types of heating, such as warm air, it is worth providing interlocks to turn off the nearby heating when doors are open.

For more exposed sites, further investment may be needed to reduce the ingress of cold air through access doors. In order of increasing cost, measures include: plastic ‘strip’ curtains, fast-acting doors, seals around delivery bays and permanent entrance lobbies with interlocked inner and outer doors. The justification for such measures should be based on reduced energy costs, improved working environment and better use of floor space adjacent to the door. The ingress of cold air, even through small openings, leads to rapid stratification and a high level of occupant complaints.

Sufficient measures should be introduced to reduce the air change rate to around 0.5 air changes per hour, provided this is compatible with the requirements of the process and the occupants.

## COMMON SAVING OPPORTUNITIES

### HEATING SYSTEM CONTROL

It is estimated that nine out of ten heating and ventilation control systems in buildings are operating inefficiently. This means that even where well-designed, efficient plant has been installed, energy is being wasted through poor control systems. Some key saving opportunities are identified below.

#### Combustion

When monitoring combustion, the aim is to achieve the minimum excess air required for complete combustion of the fuel. This involves ensuring that the $CO_2$ content of the flue gas is the maximum possible and the $O_2$ content is the minimum possible for a given firing rate, consistent with no smoke. The flue gas temperature should be as low as possible without causing condensation of moisture and sulphur oxides.

**Action:**
Regularly monitor combustion efficiencies and set target efficiencies for servicing engineers to maintain.

#### Time control

Time switches bring the plant on and off according to set times of the day. These simple devices should be used only for installations below 100 kW. A resolution better than 15 minutes should be used and a seven-day time switch, where occupancy hours differ between weekdays and weekends should be installed. Optimiser controls are suitable for most intermittently heated buildings with an installed heating capacity greater than 100 kW.

**Action:**
Ensure that time settings match occupancy requirements, and on larger installations use an optimiser.

#### Compensators

In a compensated system, the flow temperature in the heating circuit is controlled relative to the external temperature. If a building is frequently being over-heated the compensator needs adjusting.

**Action:**
Check compensator settings.

#### Night set-back temperature

The night set-back temperature is the heating set point for periods outside normal occupancy times. For areas of the factory not occupied at night (and most office areas) a night set-back of approximately 10°C is usually sufficient.

**Action:**
Check night set-back temperature is appropriate.

#### Appropriate controls

Where a space is heated by both warm air and radiant heaters it is important that the correct controls are fitted. These two types of heating need different types of time and temperature control and should not be controlled together.

**Action:**
Check suitability of controls.

# COMMON SAVING OPPORTUNITIES

## LIGHTING

It is essential that the lamp type with the greatest efficacy is used in conjunction with the correct luminaire (fitting) to meet the required lighting criteria.

### Lamp efficacy

Lamp efficacy is a measure of the effectiveness or efficiency of the lamp expressed as lumens of light output per Watt of energy consumed.

The typical efficacies of some common lamps used in industrial situations are shown in Table 7.

| Lamp type | Efficacy (Lumens/Watt) |
|---|---|
| Mercury | 45 |
| Mercury plug-in | 45 |
| Mercury D/Luxe | 50 |
| 25 mm T8 Full spectrum | 64 |
| 38 mm T12 White F/Tube | 67 |
| 25 mm T8 White F/Tube (S/G) | 77 |
| High-pressure sodium D/L | 82 |
| 25 mm T8 White F/Tube (HF/G) | 88 |
| 16 mm T5 H/F Triphosphor | 90-106 |
| 25 mm T8 H/F Triphosphor | 100 |
| High-pressure sodium | 108 |
| Low-pressure sodium/E | 138 |
| *Note:*<br>*S/G – standard electromagnetic control gear*<br>*HF/G – high frequency electronic control gear* | |

***Table 7 Lamp efficacies***

### Luminaire selection

Once the most efficient lamp type has been identified for a particular situation, you should ensure that it is utilised in an efficient luminaire. The measure of a luminaire's ability to direct light from its lamp to where it is needed is given by its Light Output Ratio (LOR). The higher the LOR, the better.

### Lighting controls

Lighting controls ensure that lighting is provided in the correct amount, at the correct place for the required time.

- Daylight-linked controls ensure that lighting will be turned off when the daylight provides the required illuminance. Where high-frequency fluorescent lighting is installed, consider using this type of control to dim the light output when ambient light levels allow.
- For manual controls, switching arrangements should at least permit individual rows of luminaires parallel to windows or under roof lights to be controlled separately. Switches should be as near as possible to the luminaires that they control. If groups of switches are used, simple labels should aid manual control.

### Management of lighting

Lighting installations need to be proactively managed if the lowest energy consumption is to be obtained. As with heating, lighting should be zoned to allow for different light level requirements, and so that appropriate control regimes can be applied to all areas. Good maintenance, with regular cleaning of luminaires, is essential if the required light levels are to be maintained, especially in dirty industrial environments.

# APPENDIX 1 IDENTIFYING THE BUILDINGS-RELATED ENERGY CONSUMPTION

## INTRODUCTION

The benchmarking process can be applied to a whole site, groups of buildings, individual buildings or particular areas of a building. The choice will be limited by the metering arrangements of the site, but it is recommended that wherever possible individual buildings are benchmarked.

In the case of large buildings housing a range of activities that need different internal temperatures, these may require the installation of temporary or permanent sub-meters. Note that the 2000 Building Regulations (Approved Document Part L2) require far more sub-metering than previously required.

Monitoring and targeting systems and the half-hourly data from 'code 5' tariff electricity meters should be used where available to assist in identifying some loads, particularly base loads and certain large process loads. The minimum requirement for the benchmarking process is the annual consumption of electricity and monthly consumption of fossil fuel in the areas to be benchmarked. There will be circumstances, such as where the process energy varies from month to month, where additional sub-metering will be needed to separate buildings-related energy from process energy.

This Appendix explains the data required and how some secondary data may be derived by calculation. Note that the benchmarking tool will automatically perform all the calculations needed.

## IDENTIFYING THE ENERGY THAT GOES TO HEAT THE BUILDING

To assess the thermal performance of the building, it is necessary to first identify the proportion of the site's annual energy consumption (both electricity and fossil fuel) which is usefully used to heat the building. The underlying methodology used by the benchmarking tool was developed following detailed observations of the energy consumption pattern in over 50 industrial buildings.

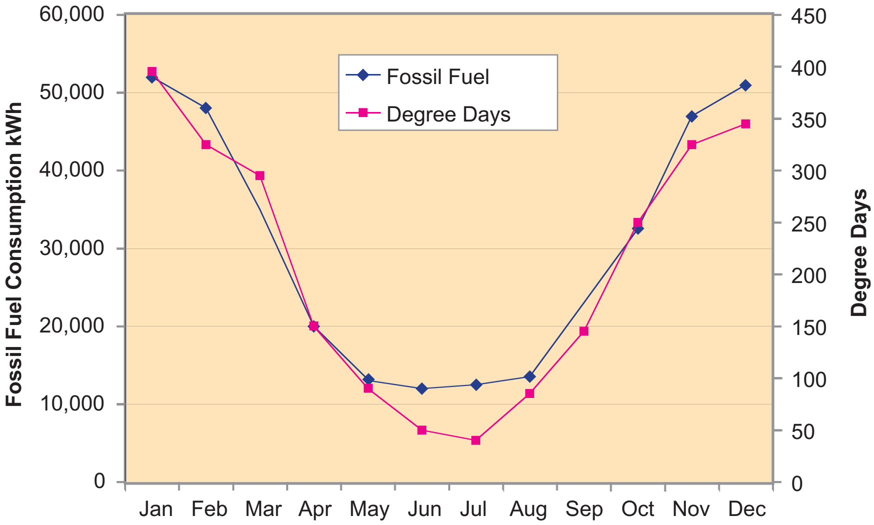



*Figure A1.1 Typical fossil fuel consumption at an industrial site compared with the local degree days*

For many industrial sites where there is a process requirement for fossil fuel, the monthly fossil fuel consumption is made up of a roughly constant amount plus a weather-dependent component required to heat the building during the heating season. (Domestic hot water is usually a very small part of the total consumption in factories, typically less than 3%). The weather component depends on the extent to which the external temperature is below the required internal temperature. Published degree day data provides a measure of this difference, averaged over each month (see Appendix 3).

Figure A1.1 shows a site's monthly fossil fuel consumption over a year compared with the local degree days.

For this site the fuel consumption over May, June, July and August is fairly constant (around 12 500 kWh) and is a measure of the monthly consumption of the process. As the weather becomes colder, (shown by increasing degree days) the fuel used by the heating systems increases accordingly.

## IDENTIFYING THE BUILDINGS-RELATED ENERGY CONSUMPTION

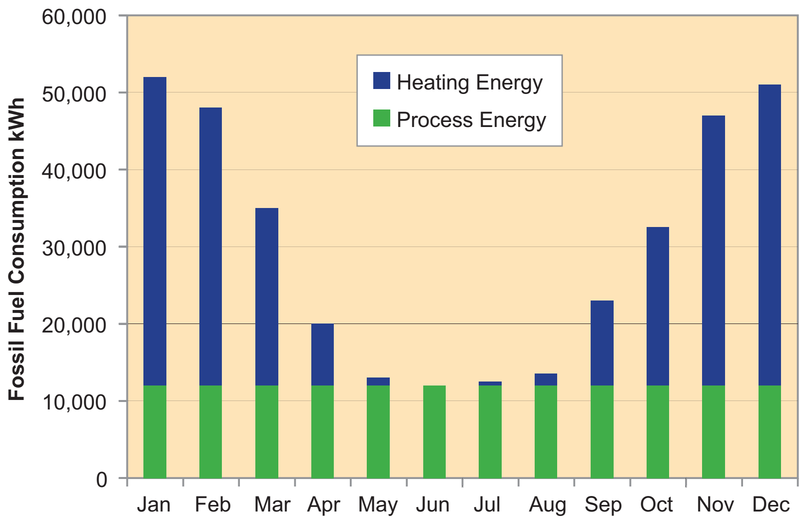



*Figure A1.2 Identifying fossil fuel used for heating and process*

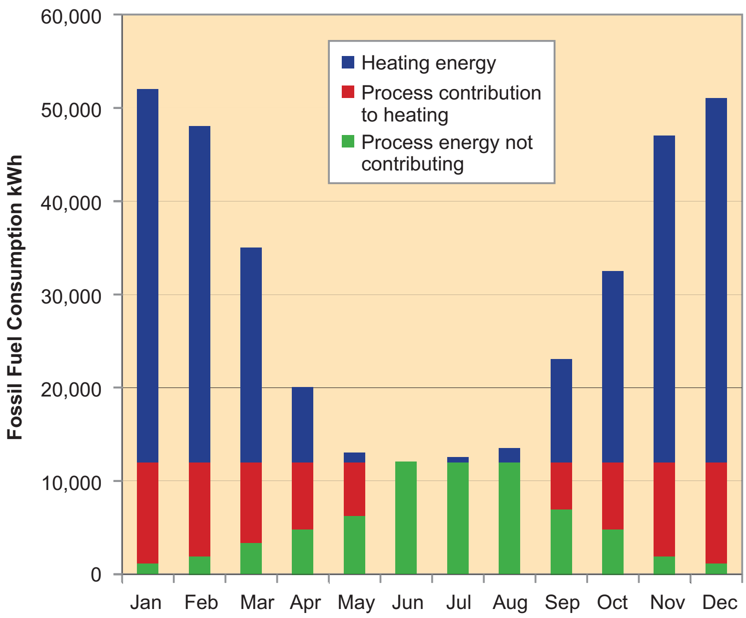



*Figure A1.3 Identifying the proportion of process energy usefully heating the building*

The energy used by the building's heating system is the difference between the total monthly consumption and the approximately constant monthly process consumption. This is illustrated by the blue areas in Figure A1.2

If the process energy consumption is not reasonably constant through the summer months (perhaps due to shut downs), it may be necessary to relate the consumption to production volumes. The consumption in the summer months is then used to derive a specific consumption for production volumes and this can then be scaled up to the annual production level. The buildings-related consumption is the difference between the total consumption and the calculated annual process fossil fuel consumption.

If the process consumption is varying such that it cannot be related to production volumes then you will need to either install sub-metering to monitor it or find some other way of estimating the monthly consumption, such as the energy consumed per batch or firing cycle. The benchmarking tool provides the option of inputting monthly consumption data.

In factories, part of the process energy that is released into the building during the heating season will contribute to keeping the building warm. This is illustrated in Figure A1.3 where that part of the process energy marked in red contributes to heating the building. Process energy that is transferred to a coolant system or is vented direct to the atmosphere does not contribute to the heating and needs to be separately identified (as the annual kWh rejected) when entering data into the benchmarking tool.

The total energy input to heat the building is the combination of the red and blue areas, ie the input from the heating system plus the useful gains from the process. Based on the 50 sites surveyed, the useful gains from the process are found to correlate with the ratio of annual process

## IDENTIFYING THE BUILDINGS-RELATED ENERGY CONSUMPTION

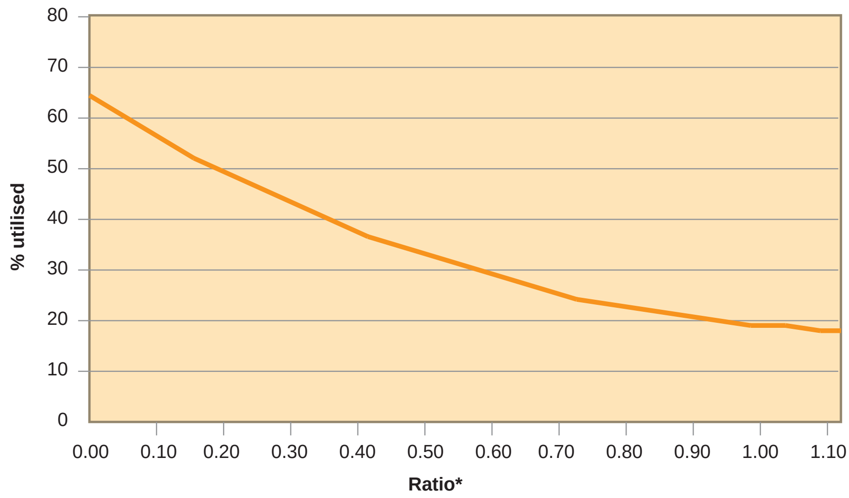
energy (kWh) to annual consumption by the heating system (kWh) per unit height. Depending on the nature of the process, between 18% and 62% of the annual process energy consumption released into the building can be usefully utilised. The higher proportions occur when the process energy is small compared with the heating load for the building, see Figure A1.4.

Where the process requires ventilation there will be an additional demand on the heating system because of the need to warm the make-up air from the outside temperature to the required internal temperature. This is illustrated in Figure A1.5 by the additional weather-related energy consumption marked in yellow.

In order to calculate a performance indicator for the building you need to know the energy that would be consumed by the stand-alone building, ie process-neutral conditions. To do this, take the weather-related part of the energy consumption, add the useful contribution from the process, but subtract the extra heat load due to process-related ventilation ie the sum of the red and blue areas on Figure A1.5. You will need to know the process ventilation rate. This can usually be estimated from duct size and either design or measured velocities, typically 5 m/s for small ducts (0.3 m x 0.3 m) rising to 10 – 20 m/s for larger ducts. Figure A1.6 provides a quick estimate of the extra heat load per hour of operation when extraction is through ducts. When extraction is by roof fans, the estimate should be based on the combined extract capacity of the fans.

### IDENTIFYING THE BUILDINGS-RELATED ELECTRICITY CONSUMPTION

Process-related electricity is considered in this Guide only in so far as it affects the building environment. Heat released through the use of electricity may contribute to heating the building. For energy-intensive processes, so much heat may be released that additional ventilation is required. Both circumstances are described earlier in this Appendix.




$$\text{* Ratio} = \frac{\text{Annual process energy (kWh)}}{\text{Annual consumption by heating system x height of building}}$$

*Figure A1.4. Percentage of process energy usefully utilised to heat the building*

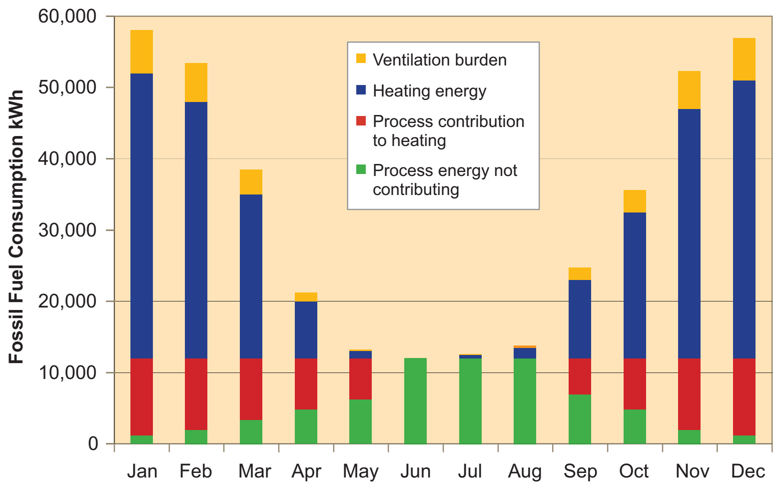



*Figure A1.5 Identifying the increased demand on the heating system caused by ventilation*

## IDENTIFYING THE BUILDINGS-RELATED ENERGY CONSUMPTION

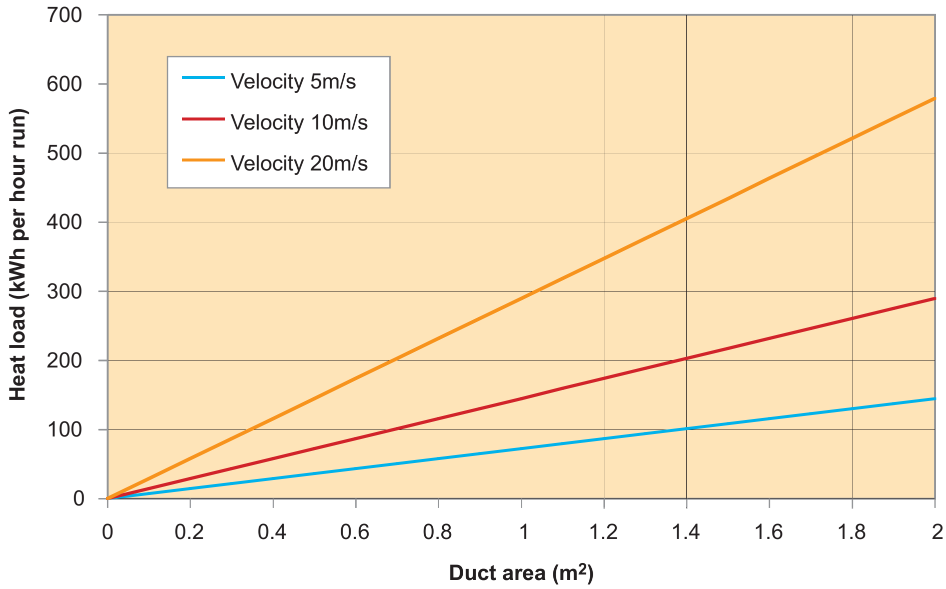



*Figure A1.6 Approximate load on heating system due to extract ventilation for hours of operation during the heating season (September to May inclusive).*

For the purposes of this Guide, electricity used to supply compressed air, motors and drives required for the processes is considered as part of the process-related energy.

Fans, pumps and controls associated with building services typically consume between 3% and 5% of the total electricity consumption. Lighting accounts for the balance of the buildings-related electricity consumption and for some activity areas such as offices, stores and warehouses, lighting is often the major user of electricity. Hence, this Guide only gives 'good practice' benchmarks for electricity consumed by lighting.

The electricity consumed by lighting can be estimated from the number of lamps installed over a given area, their circuit wattage, the hours of operation and a control factor to reflect the extent to which lights are dimmed or turned off in response to daylight (see Section 4).

# APPENDIX 2 THE ADJUSTMENT FACTORS

## INTRODUCTION

The benchmarking tool calculates a weighted average benchmark based on all the areas in the factory differentiated by internal temperature and/or hours of occupancy or by lighting level. Using the data from the input sheet for each area, the tool automatically calculates all the relevant correction factors and applies these to the 'good practice' benchmarks to derive site-specific benchmarks for each area. The average of these adjusted benchmarks, weighted according to area, is a representative benchmark for that site's location, circumstances and working practices, etc.

This Appendix summarises the automatic corrections that the benchmarking tool makes to the heating and lighting benchmarks for a site.

## ADJUSTMENT FACTORS

### Adjusting heating (fossil fuel) benchmark for different temperatures

The 'good practice' benchmarks assume an internal temperature of 19˚C applies across all production and ancillary areas. If, for example, a warehouse only needs to be heated to, say, 12˚C then the benchmark is multiplied by 0.43, see Table A2.1. An internal temperature needs to be entered for each activity area. This temperature should be appropriate for the activity. It will not necessarily be the temperature at which the area is operated.

### Adjusting heating benchmark (Table A2.1) for hours of occupancy

The 'good practice' benchmarks have been developed for lightweight buildings occupied for five days a week on a single 8-hour shift basis (see Table 1, page 5 and Table A2.2). The benchmarks for heating take account of the pre-heat periods prior to occupancy and set-back during unoccupied periods. Where the working week and/or shift patterns are different, adjustments need to be made. The correction factors depend on the structure of the building, with medium-weight buildings requiring a longer pre-heat period than lightweight buildings. The vast majority of industrial buildings are lightweight, but if a site has medium-weight buildings it is recommended that the approximated 'good practice' benchmarks in Table A2.3 (Medium-weight) are used instead of those given in Table 1 and A2.2 (Lightweight). The approximated 'good practice' benchmarks are not based on survey data, but were derived by applying crude correction factors for the thermal response of the building. As with all the heating benchmarks in this Guide, differences of ±15% between the site-specific benchmarks and PIs should not be regarded as significant.

Table A2.4 provides multiplying factors for most working patterns. When the benchmarks for light and medium-weight buildings (Tables A2.2 and A2.3) are multiplied by these factors, it can be seen that the difference between lightweight and medium-weight buildings becomes smaller as the number of hours worked per day increases. For continuous working the benchmarks are the same for both lightweight and medium-weight buildings.

| Factory area heated by fossil fuel (m²) | Benchmark consumption (kWh/m² per year) | |
|---|---|---|
| | Post-1995 | Pre-1995 |
| | Lightweight | Lightweight |
| Up to 5,000 | 96 | 107 |
| Over 5,000 | 92 | 103 |

*Table A2.2. 'Good practice' benchmarks for heating in lightweight industrial buildings*

| Factory area heated by fossil fuel (m²) | Benchmark consumption (kWh/m² per year) | |
|---|---|---|
| | Post-1995 | Pre-1995 |
| | Medium-weight | Medium-weight |
| Up to 5,000 | 130 | 145 |
| Over 5,000 | 125 | 140 |

*Table A2.3. Approximated 'good practice' benchmarks for heating in medium-weight industrial buildings*

| Required internal temperature (°C) | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Degree day correction factor | 1.29 | 1.19 | 1.09 | 1.00 | 0.91 | 0.82 | 0.73 | 0.65 | 0.57 | 0.50 | 0.43 | 0.37 | 0.31 |

*Table A2.1 Factors for adjusting degree days to different base temperatures*

## THE ADJUSTMENT FACTORS

| Days/week | Average hours/week | Multiplying factor | |
|---|---|---|---|
| | | Lightweight building | Medium-weight building |
| 5 | 40 | 1.00 | 1.00 |
| | 60 | 1.19 | 1.10 |
| | 80 | 1.39 | 1.19 |
| | 120 | 1.77 | 1.38 |
| 6 | 48 | 1.14 | 1.11 |
| | 72 | 1.37 | 1.22 |
| | 96 | 1.61 | 1.33 |
| | 148 | 2.07 | 1.56 |
| 7 | 56 | 1.28 | 1.21 |
| | 84 | 1.55 | 1.34 |
| | 112 | 1.82 | 1.48 |
| | 168 | 2.37 | 1.74 |

*Table A2.4 Fossil fuel occupancy correction factors*

**Worked example**

An existing small Pre-1995 lightweight building, 4,000 m$^2$, has area 1 (20%) heated to 20°C and occupied for five days, and an average of 40 hours per week, and area 2 (80%) heated to 16°C for six days and an average of 96 hours per week.

From Table 1 (page 5), the 'good practice' benchmark is 107 kWh/m$^2$ per year
Adjusted benchmarks = 107 x factor for temperature x factor for hours of occupancy

Area 1 Adjusted benchmark = 107 x 1.09 x 1
= 116.6 kWh/m$^2$

Area 2 Adjusted benchmark = 107 x 0.73 x 1.61
= 125.8 kWh/m$^2$

Weighted average benchmark = $\frac{(116.6 \times 20) + (125.6 \times 80)}{100}$ kWh/m$^2$ per year
= 124 kWh/m$^2$ per year

The benchmarking tool calculates the adjustment factor for any working pattern from the input data of medium or lightweight construction, number of days worked per week and the average number of hours per week (see worked example).

**Adjusting heating benchmark for site exposure**

In locations with high exposure more energy is lost from the external surfaces of the building compared to a well-sheltered building. To account for this variation, an exposure factor is used, as detailed in Table A2.5[3].

## THE ADJUSTMENT FACTORS

### Adjusting heating benchmark for the weather

Degree days are a measure of the variation of outside temperature that enables the energy consumption of a building to be related to the weather (see Appendix 3). The 'good practice' benchmarks are based on the 10-year average of 2051 degree days for the heating season (taken to be September to May inclusive). Therefore the 'good practice' benchmark needs to be adjusted to account for the actual degree days occurring at the location. The degree days are for a base temperature of 15.5°C (the temperature for the published degree days). Degree days entered into the tool are for the same base temperature, but the tool recalculates the degree days for a base temperature appropriate to the maintained temperature in each activity area. Thus the 'weather correction factor' equals the degree days (for September to May inclusive) divided by 2051.

### Adjusting heating benchmarks for centralised heating system

There are a number of industrial sites that have central boiler plant; especially where there is a requirement for process steam. The central boiler plant will normally run continuously, giving rise to large standing losses, so correction factors need to be applied to the 'good practice' benchmark. This calculation can be done, using the tool, as follows:

***In the data input screen for 'significant process impact', select 'none', 'small' or 'large' from the drop-down menus under 'distribution system size'. The tool will then apply the correction factors shown in Table A2.6, where 'small' is a site with central plant supplying up to six buildings in close proximity.***

| Distribution System size | Correction factor |
|---|---|
| None (ie decentralised) | 1.00 |
| Small | 1.25 |
| Large | 1.40 |

*Table A2.6 Correction factors for centralised heating systems*

This calculation procedure assumes that the heating system is controlled by thermostats and timers to suit the occupancy requirements of the building. Note: these factors show the clear energy benefits associated with decentralisation.

### Adjusting lighting benchmarks for lighting levels

The general lighting levels being achieved in different areas of the factory will be only approximately known. Rather than try to estimate the lighting levels, it is recommended that the site-specific benchmarks are set according to the discrimination of detail needed. The benchmarking tool allows 300 lux where no discrimination of fine detail is required and 500 lux for a medium level of discrimination. The corresponding levels for racked storage areas are 150 and 300 lux respectively. Selecting 'no discrimination' or 'medium discrimination' in the tool sets the site-specific benchmark for the appropriate lighting level.

The benchmarks should not be applied to specialist task lighting. Where the task requires higher levels of illumination this should be supplied by designated task lighting rather than by increasing the general level of illumination. The Society of Light and Lighting's 'Code for Lighting 2002'[1] recommends lighting levels for a wide range of tasks.

| Exposure | Correction factor |
|---|---|
| **Sheltered:**<br>The building is in a built-up area with other buildings of a similar or greater height surrounding it. | 0.9 |
| **Normal:**<br>The building it is on level ground in urban or rural surroundings.<br>It would be usual to have some adjacent buildings or trees. | 1.0 |
| **Exposed:**<br>Hilly or coastal sites with little or no adjacent screening from the prevailing wind. | 1.1 |

*Table A2.5 Exposure correction factors*

# APPENDIX 3 DEGREE DAYS

## INTRODUCTION

Buildings lose heat through two main mechanisms:

- by air moving through the building, entering and leaving through windows, doors, gaps in the fabric and ventilators
- by conduction through the walls, floor, ceiling, doors and windows.

In each case the rate of heat loss is directly proportional to the number of degrees by which the outside temperature is below that of the inside temperature. This difference will vary across the day and with the seasons. For any period, degree days are defined as:

- the average number of degrees by which the outside temperature on any given day is less than a base temperature, totalled for all the days in the period.

The base temperature is the temperature above which the building does not need heating and is somewhat less than the required internal temperature to reflect the fact that internal gains contribute to the heat input to the building.

Degree days for a base temperature of 15.5°C for 18 areas of the UK are published in the 'Energy and Environment Management Journal' and are also posted on the Energy Efficiency Best Practice programme website.[4]

The benchmarking process requires monthly degree days at the site to be entered on the data input sheet. Most published degree days are for a base temperature of 15.5°C. For stand-alone industrial buildings (process neutral) there are few internal gains. On the basis that most industrial buildings are maintained at about 19°C, a degree day base temperature of 18°C is used for the 'good practice' benchmarks to reflect the small amount of gains that contribute to heating these buildings.

However, many areas of a factory, such as unoccupied stores and warehouses, do not need to be heated to 19°C – even though many are. The data input sheet allows different internal temperatures to be entered for different areas in the factory.

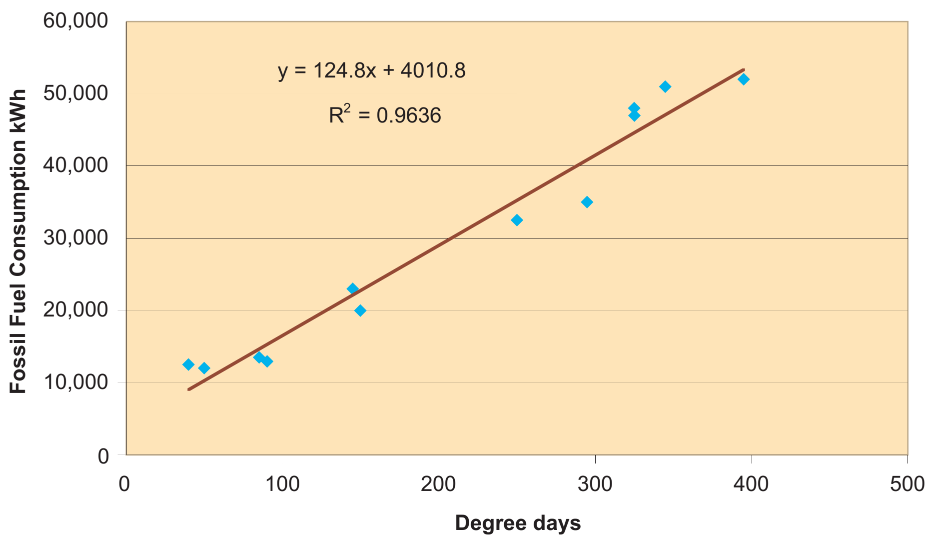



*Figure A3.1. Correlation of fuel consumption with degree days*

## DEGREE DAYS

The benchmarking tool will automatically adjust the published degree days (base temperature 15.5°C) to degree days for a base temperature appropriate to each area. The 'good practice' benchmarks are based on the 10-year average of 2051 degree days to a base temperature of 15.5°C over the heating season September to May inclusive.

To check on the consistency of the energy consumption data provided on the data input sheet, the benchmarking tool automatically plots energy consumption against degree days. Figure A3.1 is an example.

The straight line fit through the data in this example has a high correlation, ($R^2$ = 0.96 – the closer $R^2$ is to 1.0 the better). This indicates that the heat input from the heating system is indeed proportional to the number of degrees the external temperature is below the internal temperature and also that the monthly process energy consumption is reasonably constant. This verifies the underlying assumptions of the benchmarking process and, in this case, we can have a high level of confidence in the PI calculated from the monthly consumption data.

Where the degree day plot has a poor correlation, ($R^2$ values less than 0.5) this may be due to errors in the data or it may indicate that the heating is badly controlled and/or the internal temperature varies across the heating season. Alternatively, it may mean that the monthly process consumption is varying. If this is the case, you will need to either meter the monthly process consumption, or estimate it by some method such as the energy per batch or firing cycle. The benchmarking tool has an option to enter monthly process consumption.

If the correlation remains less than 0.5, the benchmarking tool will not operate because the underlying assumptions in the benchmarking process are not fulfiled and any comparison between the PI and benchmark may be unreliable and could be misleading. That said, the data for most industrial buildings do correlate well with degree days.

# APPENDIX 4 SUMMARY OF SURVEY DATA

## INTRODUCTION

### Heating performance

The Energy Efficiency Best Practice programme commissioned a survey of the energy performance of industrial buildings. The survey was based on a representative sample of the existing industrial building stock, ranging in size from under 1,000 m$^2$ to over 25,000 m$^2$. Buildings were put into age groups according to when significant improvements were required by changes in the Building Regulations. There are three main age groups: pre-1976, 1976 to 1990 and post-1990. The survey also identified buildings that have undergone significant refurbishment to improve their energy performance. For each of these buildings a performance indicator (PI) was calculated for the stand-alone building (ie process-neutral conditions, standard degree days and 5-day single shift working).

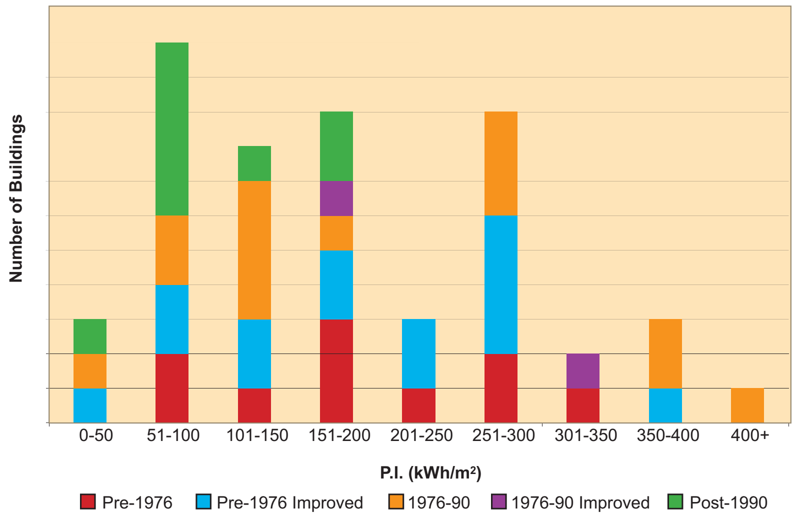



*Figure A4.1. Distribution of heating PIs by age of building*

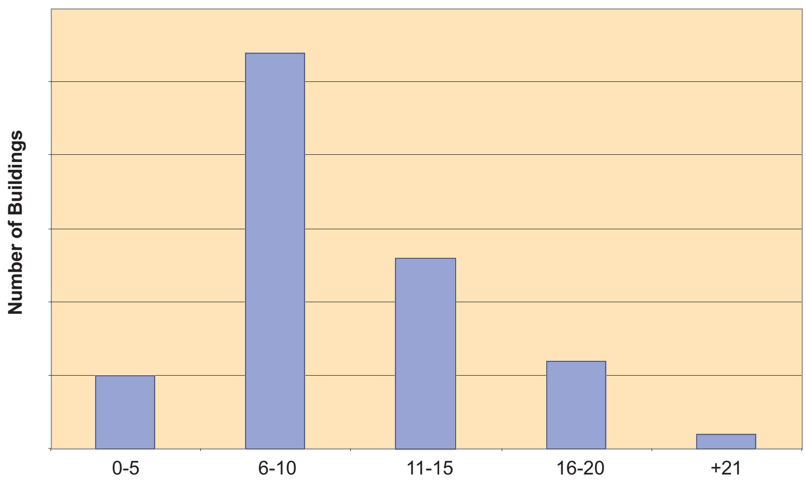



*Figure A4.2 Distribution of lighting installed loads (W/m$^2$)*

There is a very large variation in the PIs for the survey sample, from under 50 to over 400 kWh/m$^2$ per year (see Figure A4.1).

There are many factors that can affect the heating performance, but the main contributory factor to the worst performances is poor operational practices. For the worst cases, heating systems are often poorly controlled leading to overheating, while at the same time air change rates are very high due either to leaky fabric or poor management of large access doors. An important observation from the survey is that older buildings that have been refurbished have a performance on a par with the best of the newer buildings, showing that it is possible to make very significant energy savings in the majority of existing buildings.

### Lighting performance

The survey included details of the lighting installed in each area of the buildings, from which the installed load in W/m$^2$ was calculated (see Figure A4.2). For most production and warehouse areas the installed load was typically in the range 6 to 10 W/m$^2$.

Although some lower values were recorded, these were generally associated with low lighting levels rather than efficient systems. Lighting levels in the integral factory offices were generally higher than the general lighting for production and warehouse areas.

# APPENDIX 5 CONVERSION FACTORS

| Fuel type | Unit of supply | | | kgC/kWh |
|---|---|---|---|---|
| Electricity | 1 kWh | = | 1 kWh | 0.127 |
| Natural gas | 1 $m^3$ | = | 10.6 kWh | 0.052 |
| | 1 kWh | = | 1 kWh | |
| | 100 $ft^3$ | = | 30.3 kWh | |
| Gas oil (35 sec) | 1 litre | = | 10.6 kWh | 0.069 |
| Light fuel oil (290 sec) | 1 litre | = | 11.2 kWh | |
| Medium fuel oil (950 sec) | 1 litre | = | 11.3 kWh | |
| Heavy fuel oil (3500 sec) | 1 litre | = | 11.4 kWh | |
| Coal | 1 kg | = | 9 kWh | 0.081 |
| Propane | 1 kg | = | 13.9 kWh | |
| Butane | 1 kg | = | 13.7 kWh | |

*Note the carbon emissions for electricity changes with the primary fuel mix used to generate. In the UK it is currently falling.*

***Table A5.1 Conversion factors for various fuels***

**CONVERSION FACTORS**

| | | |
|---|---|---|
| 3.6 MJ | = | 1 kWh |
| 3.6 GJ | = | 1000 kWh |
| 100 000 Btu | = | 1 therm |
| | = | 29.31 kWh |
| 100 $ft^3$ | = | 28.3 $m^3$ |

To convert the lighting PI in $W/m^2$ into energy consumed in $kWh/m^2$ per year, multiply by the effective hours of operation and divide by 1000. See **[5]** and **[6]** for guidance on effective hours of operation.

# REFERENCES AND FURTHER READING

## REFERENCES

[1] 'Code for lighting 2002', Society of Light and Lighting, CIBSE
[2] 'Focus – the manager's guide to reducing energy bills', Energy Efficiency Best Practice programme, 2000
[3] CIBSE Vol B, Installation and equipment data
[4] www.energy-efficiency.gov.uk/info/online_resources/degree/degree.htm
[5] 'Technical memorandum 22' (TM22), CIBSE, 1999
[6] 'Energy efficiency in lighting for industrial buildings – A guide for building managers', Good Practice Guide 158, Energy Efficiency Best Practice programme.

## FURTHER INFORMATION

There are numerous sources of further information, including:

**Chartered Institution of Building Services Engineers**
222 Balham High Road, London SW12 9BS.
Tel 020 8675 5211. Fax 020 8675 5449.
www.cibse.org

- Guide F Energy Efficiency in Buildings
- Technical Memorandum TM23 'Testing Buildings for Air Leakage'

**Department of Transport, Local Government and the Regions (DTLR)**
www.dtlr.gov.uk

- Building Regulations 2000 Approved Document L2 (2002 edition)

**Energy Efficiency Best Practice programme**
www.energy-efficiency.gov.uk
Environment and Energy Helpline on 0800 585794

## BEST PRACTICE PROGRAMME DOCUMENTS

The following Energy Efficiency Best Practice Programme publications are available from the Environment and Energy Helpline 0800 585794

**Energy Consumption Guides**
19 Energy use in offices
75 Energy use in Ministry of Defence establishments

**Good Practice Case Studies**
388 Process Combustion Ltd
390 Shell UK Exploration and Production
391 Marconi Applied Technologies

**Good Practice Guides**
158 Energy efficiency in lighting for industrial buildings – A guide for building managers
300 Installer's guide to lighting design
303 The designer's guide to energy-efficient buildings for industry
304 The purchaser's guide to energy-efficient buildings for industry
310 Degree days for energy management - a practical introduction
319 Managing energy in warehouses

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**Energy Consumption Guides:** compare energy use in specific processes, operations, plant and building types.

**Good Practice:** promotes proven energy-efficient techniques through Guides and Case Studies.

**New Practice:** monitors first commercial applications of new energy efficiency measures.

**Future Practice:** reports on joint R&D ventures into new energy efficiency measures.

**General Information:** describes concepts and approaches yet to be fully established as good practice.

**Fuel Efficiency Booklets:** give detailed information on specific technologies and techniques.

**Introduction to Energy Efficiency:** helps new energy managers understand the use and costs of heating, lighting, etc.